Millimeter-wave Experimental Facilities for ROF Multiple Service Road-Vehicle Communications

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1.Introduction

Wireless communication system between roadside base station and vehicles are expected to become basic infrastructures for the ITS (Intelligent Transport Systems), since various kinds of information including vehicle control signals, navigation information and multimedia information etc for the safety and comfortable drive should be supplied timely to the vehicles running on the road. CRL Yokosuka (Yokosuka Radio Communications Research Center, Communications Research Laboratory, MPT Japan) has intensively set up millimeter-wave test facilities in order to accelerate research activities on the ITS wireless communications.

In this paper, we introduce the road-vehicle communications test facilities based on the Radio On Fiber (ROF) transmission system and micro-cell network system along a road in the YRP (Yokosuka Research Park). In these facilities, millimeter-wave frequency bands of 36~37GHz as the experimental band are used. A control station is located on the 3rd floor of a research building and 12 antenna poles for the roadside base stations are put up in the equal interval of 20 meters along an about 200 meters straight line road. Optical fiber cables are installed in the state of a star connection between the Control Station (CS) and each roadside Local Base Station (LBS). Propagation characteristics between the roadside antenna and a vehicle are presented and overall transmission system including optical fiber cable section and air section are also mentioned in this paper.

2.Configuration of the proposed ROF system [1],[2]

Nowadays the number of communications equipment of the car, especially antenna, has been increased, because many services such as Vehicle Information & Communication System (VICS), TV broadcasting and mobile communications are available on different frequency bands. As a result, the car looks like a “hedgehog”. However, by using the common frequency band, the number of air interface between the car and the wireless service network is drastically decreased. This is an important factor from the view points of not only the car design but also the efficient frequency use.

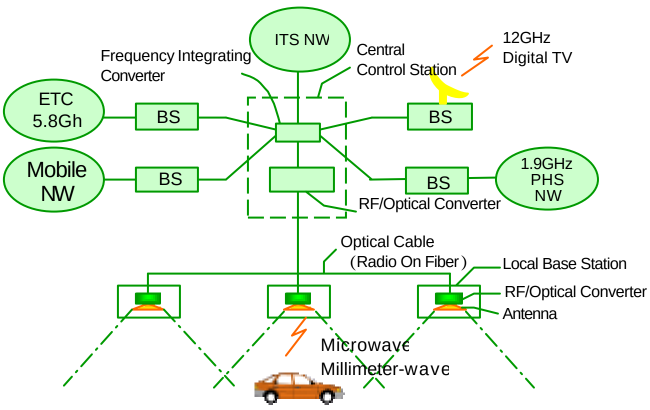

Fig.1 Concept of the ITS multiple service network based on CFB-ROF system

Figure 1 illustrates the concept of the ITS multiple service network based on the Common Frequency Band Radio On Fiber (CFB-ROF) transmission. In this technique, first of all, we up-convert the radio frequencies of various wireless services into the common frequency band. The users of the ITS can use this common specified frequency band for the ITS multiple service communications. For the down-link of this system, the combined electrical radio signal, which is converted to the common frequency band, drives EAM and the modulated optical signal is delivered to the Local Base Station (LBS). Then, by using PD, the optical signal is converted to the radio signal and is transmitted to the vehicle from the roadside antenna. The vehicle has only to have one antenna which matches with the common frequency band and receives the radio signal from the LBS. In the vehicle, the radio signal is down-converted and divided into the original band of each service. Finally, the signal is carried to the each terminal on the original band by the distributor. The distributor may be equipped with several connectors for the distribution to the each mobile terminal. We can connect the distributor and each off-the-shelf terminal with a cable. If we use a multi-mode terminal, it is not necessary to distribute the received signals to each terminal. Multi-mode terminal is expected to be realized by adopting the software defined radio technology. Furthermore, multi-mode terminal will make a contribution for the efficient space use in a vehicle. For the up-link, the procedure is the reverse of the down-link.

3.Experimental Facilities for RVC

Figure 2 shows the configuration of the experimental facilities for the ROF transmission system of three kinds of mobile services such as Electric Toll Collection (ETC), Personal Handy Phone (PHS) and TV broadcasting in Japan. In these experimental facilities, 36~37 GHz band is used as the common frequency band and the frequency for each service is allocated as shown in Figure 3.

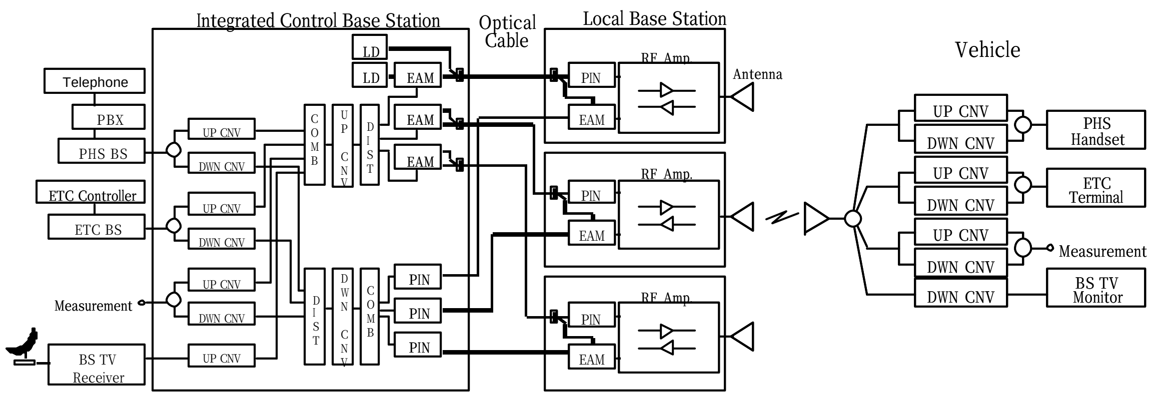

Fig.2 Configuration of the experimental facilities for the multiple service CFB-ROF transmission system

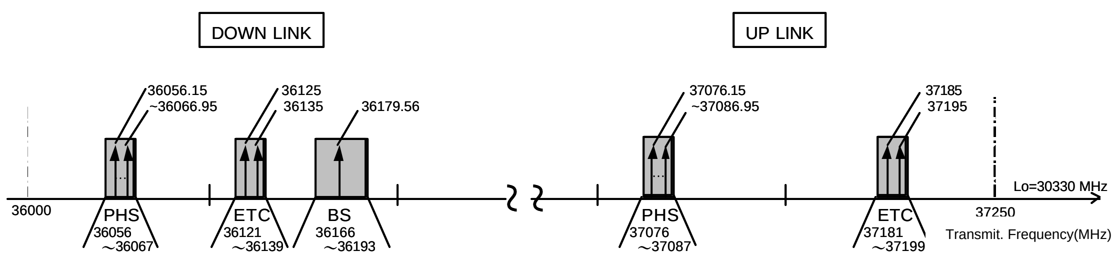

Fig.3 Frequency allocation of multiple service ROF transmission system in 37GHz band

The wavelength and the output power of the laser diode for this scheme is in 1.5 μm region and about 0dBm, respectively. The length of optical fiber cable section between Control Station in the research building and the roadside LBS is about 700 meters. The frequency bands for the down link and up link are 36.00~36.50GHz and 36.75~37.25GHz, respectively. The frequency bands of the RF amplifiers and antennas for the LBS and the vehicle match with these frequency bands.
We have prepared two kinds of roadside antenna. One is the horn antenna and the other is the patch antenna with 20 element antennas and both of them have the cosec-squared beam pattern on the vertical plane. The interval between roadside antennas is 20meters.
The antenna, the frequency converter and the mobile terminals are mounted in the vehicle. The original frequency bands of PHS and ETC are in 1.9GHz and 5.8GHz region, respectively. Therefore, the received RF signals are divided and delivered into the each mobile terminal after frequency down conversion in the vehicle.
Figure 4(a) is a photo of the Control Station and the roadside antennas are shown in Fig.4(b).

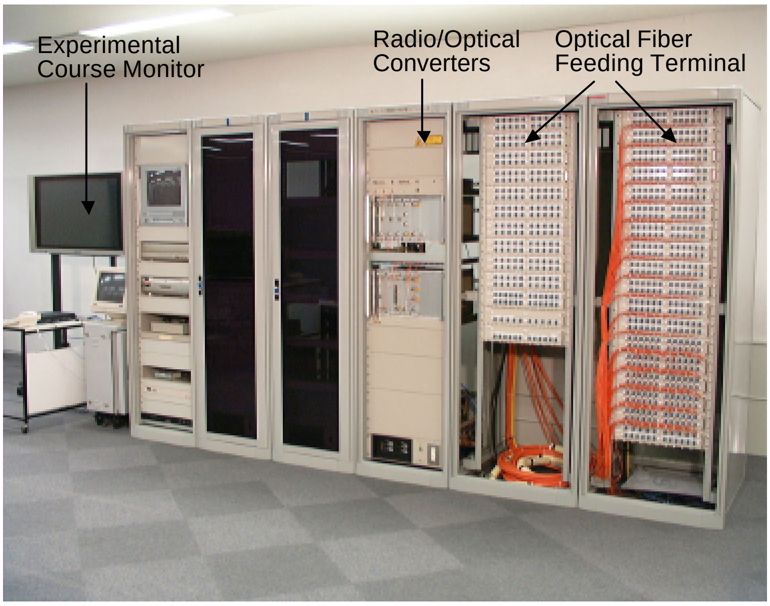

Fig.4(a) Facilities for ROF Control Station

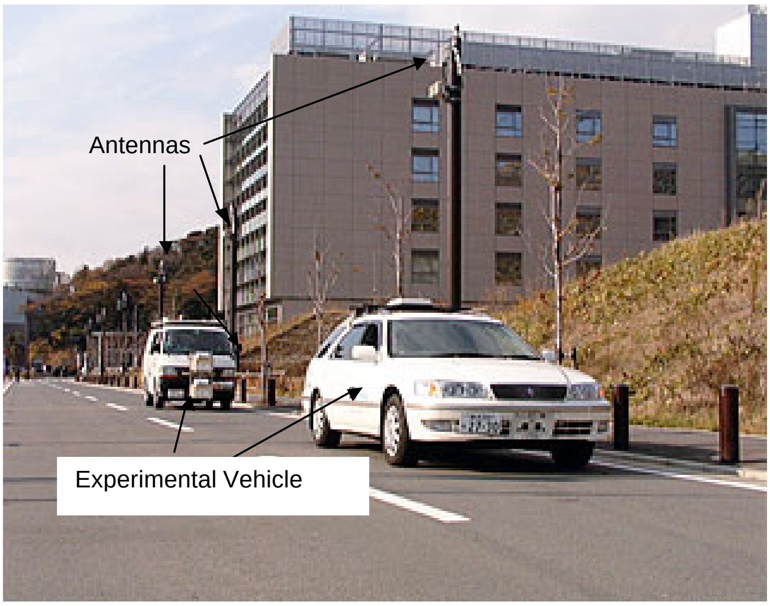

Fig.4(b) ITS experimental test course at YRP

4. Estimation of received power for ROF road-vehicle communication

Next, we estimate the received power at the Mobile Station (MS). In this system, three LBSs connected to one CS transmit same frequency radio wave to the vehicle. It is predicted that the strong interference can be observed at the boundary area between two cells covered by different LBSs.

In this simulation, each LBS is on the 5m-height of the pole installed along the road and the poles at roadside are lined 20meters interval. The height of vehicle antennas is 2.1meters. So the height deference between LBS and MS antennas is 2.9meters. In this estimation, the transmitted power is 10dBm and the frequency is 36.06155GHz. The transmitting antenna has cosec-squared beam pattern on the vertical plane. This antenna enables us to get almost same received power in the coverage area. The receiving antenna on the vehicle has pencil beam pattern with 3dBi gain. We did not consider the reflection from road or other objects.

Figure 5 (a) shows the contour map of calculated received power of 5.0m x 40.0m area on the road. Antenna poles stand in the 20 meters interval along the roadside. Figure 5 (b) shows the received power at 2.1m height from road surface and on the center of lane, i.e., 2.5m from edge of road. The variation of the received power as a function of position is caused by the interference of the radio waves from several LBSs. The interference between LBSs causes very complicated fluctuations of received power. This result shows that we need to develop some new technologies, for example, some kind of diversity with very high-speed signal-selection.

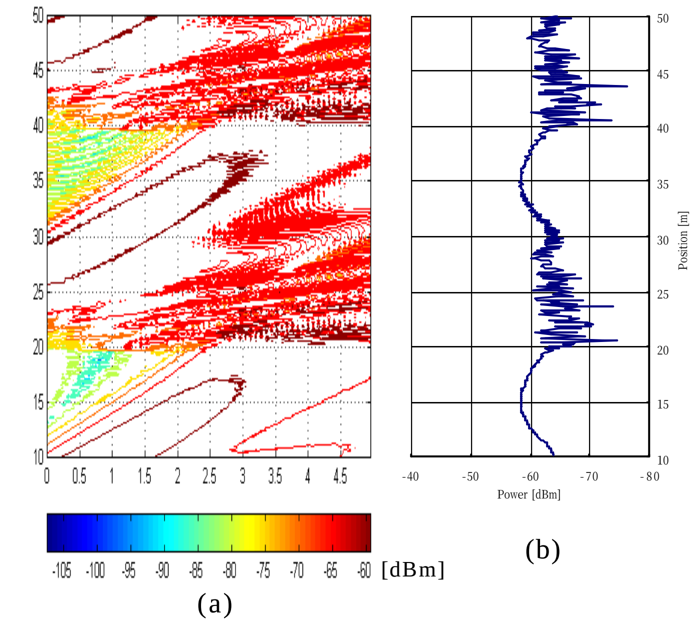

Fig.5 Contour map of calculated received power (a), and received power variation on the center of the lane (b).

5.Conlusions

In this paper, we have presented research activities of the ROF technology for the ITS. Especially, we have explained test facilities for the ITS experiments. We are studying a future wireless communication network based on ROF multiple service transmission system, in which we will be provided with multimedia mobile communication services.

References

[1] M. Fujise, H. Harada, "Multimode DSRC by Radio On Fiber", in proc. of the 1998 Communication Society Conference of IEICE, SAD-2-8, pp.32-33, Sep.1998.

[2] M. Fujise, K. Sato and H. Harada, "New Road-Vehicle Communication Systems Based on Radio on Fiber Technologies for Future Intelligent Transport Systems (ITS)", in proc. of the First International Symposium on Wireless Personal Multimedia Communications (WPMC'98), pp. 139-144, Nov. 1998.